HETTA LAKE
SOCKEYE SALMON (*Oncorhynchus nerka)*
STOCK ASSESSMENT PROJECT
2002 ANNUAL REPORT

By

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and
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ABSTRACT

Hetta Lake sockeye salmon are an important subsistence resource for the people of Hydaburg. The Hetta Lake Sockeye Salmon Stock Assessment Project was initiated because of concerns about the apparent declines in sockeye salmon returning to Hetta Lake. The project evaluates sockeye salmon production at various life stages and assesses lake productivity. This annual report summarizes work conducted during the second year of the project, 2002. The mid-water trawl catch was 81% sockeye fry and 19% sticklebacks. The hydroacoustic survey estimated sockeye fry density at 0.45 fry per m^2 and the total lake estimate was 1.2 million sockeye fry. We were unable to estimate the adult returns because of the low number of sockeye spawners present in the study area (about 300 fish). The subsistence harvest was estimated to be 950 sockeye salmon. Hetta Lake had a seasonal mean zooplankton density of 11,700 plankters per m^2 and a seasonal mean weighted biomass of 46 mg per m^2. The seasonal mean euphotic zone depth was 10.2 m. This year's results provide the foundation for a multiple-year study to assess the health of the sockeye salmon stock in Hetta Lake and to set a range of escapement goals capable of sustaining this population for many generations.

KEY WORDS: sockeye salmon, *Oncorhynchus nerka*, Hetta Lake, Prince of Wales Island, stock assessment, limnology, zooplankton, hatchery, harvest, subsistence, escapement, hydroacoustic

INTRODUCTION

Hetta Lake is historically one of the most productive sockeye salmon systems in Southeast Alaska. The people of Hydaburg and the ADF&G are concerned by the apparent decline in sockeye salmon escapement to Hetta Lake. During the two years that this project has been in operation, estimates of escapement have been very low. Numerous activities may have influenced the production of sockeye salmon in this system. In addition to a long history of commercial and subsistence harvest and an early hatchery operation, the Hetta Lake watershed was extensively logged in the 1950s. Since Hetta Lake is an important sockeye salmon subsistence system to the community of Hydaburg, state and federal agencies in conjunction with the Hydaburg Cooperative Association initiated the Hetta Lake Sockeye Salmon Stock Assessment Project in 2001. The Hetta Lake Project identifies and outlines a set of objectives to begin assessing the health of this sockeye salmon stock. The purpose of the study is to begin identifying major factors that may be limiting production. This multiple-year study is intended to gather information about the Hetta Lake sockeye salmon population and habitat to set an escapement goal range and monitor the response of the system to this range to determine if they are sustainable. This report summarizes the sockeye salmon stock assessment data collected in 2002.

OBJECTIVES

1. Estimate escapement of sockeye salmon into each lake so that the estimated coefficient of variation is less than 15% using a mark-recapture program.
2. Estimate the age, length, weight, and sex composition of the sockeye salmon in indexing samples from each lake.
3. Estimate sockeye fry densities using hydroacoustic and mid-water trawl methods so that the estimated coefficient of variation is less than 10%.
4. Estimate the subsistence sockeye salmon harvest from Hetta Lake so that the estimated coefficient of variation is less than 15%.
5. Collect baseline data on in-lake productivity of each lake using established ADF&G limnological sampling procedures, which may include water chemistry, zooplankton sampling, hydroacoustic fry assessments, and smolt sampling.

Changes to Objectives

Measures of variability and precision thresholds were added to the original objectives to evaluate the study design and make changes if necessary.

STUDY SITE

Hetta Lake (ADF&G stream #103-25-047) is located on the southwestern side of the Prince of Wales Island (55°10'10" N., 132°34' 02" W.; Figure 1). The lake has a surface area of 207 hectares, an elevation of 9.4 meters, a mean depth of 48.0 meters, and a maximum depth of 92.0 meters (Figure 2). This dimictic oligotrophic lake has stained water and a volume of 99.4 million cubic meters with a mean residence time of 12.6 months. The mean euphotic zone depth is 11.7 meters. The Hetta Lake watershed is composed of 5,828 acres of steep spruce, cedar, and hemlock forest with alpine habitat above 550 m. Hetta Lake has three main tributaries, Hetta, Hatchery, and Camp creeks. The Outlet Creek, empties into Hetta Cove approximately 600 m from the lake. Native fish species include cutthroat trout (*O. clarki* spp.), Dolly Varden (*Salvelinus malma*), three spine stickleback (*Gasterosteus aculeatus*), cottids (*Cottus* sp.), steelhead (*O. mykiss*), and pink (*O. gorbusha*), chum (*O. keta*), coho (*O. kisutch*), and sockeye (*O. nerka*) salmon.

METHODS

Sockeye Fry Assessment

Hydroacoustic and mid-water trawl sampling estimates the distribution and abundance of sockeye salmon fry in Hetta Lake. Prior to conducting the survey, Hetta Lake was divided into 8 sections based on lake area and shape. Ten evenly spaced orthogonal transects were identified within each section and two of these were randomly selected to be surveyed. Transects selected in 2002 became permanent and will be repeated during future surveys. The decision to keep the transects fixed each year, reflects a decision to emphasize measurements in year-to-year change in population size.

We surveyed each selected transect from shore to shore, beginning and ending the sampling at the depth of 10 m. Sampling was conducted during the darkest part of the night. A constant boat speed of about 2.0 m $\cdot$ sec^{-1} was attempted for all transects. The acoustic equipment consisted of a Biosonics[2] DT-4000™ scientific echo sounder[1] (420 kHz, 6° single beam transducer) and Biosonics Visual Acquisition © version 4.0.2 software was used to collect and record the data. Ping rate was set at 5 pings $\cdot$ sec^{-1} and pulse width at 0.4 ms. Only target strengths ranging between –40 dB to –68 dB were recorded because this range represents fish within the size range of juvenile sockeye salmon and other small pelagic fish.

Midwater trawl sampling was conducted in conjunction with the hydroacoustic surveys to determine the species composition of pelagic fish and the age distribution of sockeye fry. A 2 m

[1] Product names used in this publication are included for scientific completeness but do not constitute product endorsement.

x 2 m elongated beam-trawl net with a cod-end is used for the trawl sampling. Trawl sampling was conducted in the area of the lake with the highest concentration of fish, identified during the hydroacoustic survey. An exploratory surface tow was conducted to determine if there are fish on the surface not detected by the down-looking hydroacoustic gear. A surface tow was conducted on all clear and stained lakes in 2002 and will not be repeated in future surveys if fish were not present. The surface tow was conducted by attaching floats to the top of the tow net so that it floated just beneath the lake surface 30 m back from the boat. Additional tows were conducted at two depths, also identified during the hydroacoustic survey, in the same area of highest fish concentration. Two replicate tows are conducted at each depth. The second tow, at a given depth, was started at the termination point of the first tow. The direction of the second tow for each depth was selected such that it does not sample the same area as the first tow. The trawl duration ranged from 15 to 30 minutes, depending on fish density and lake size and morphology. If warranted, a second complete set of tows was conducted in a morphologically distinct section of the lake and in a second area of high fish densities.

All adult fish caught in the midwater trawl were identified, counted, and released. All small fish from the trawl net were euthanized with MS 222. Fish were preserved with 90% alcohol. Samples from each tow were preserved in separate bottles. The bottle was labeled with the date, lake name, tow number, tow depth, time of tow, and initials of collectors. Fish captured in the tow samples were analyzed at the laboratory to determine species composition and age distribution of sockeye juveniles. The species composition of the midwater trawl samples was applied to the total target estimate to calculate each species-specific population. The sockeye fry density for the entire lake was also calculated using the sockeye fry composition.

In the laboratory, fish were soaked in water for 60 minutes before sampling to re-hydrate the samples. All fish were identified and the snout-fork length (to the nearest millimeter) and weight (to the nearest 0.1 gram) were measured on each fish. All sockeye salmon fry under 50 mm were assumed to be age-0. Scales were collected from sockeye fry over 50 mm and mounted onto a microscope slide for age determination. Sockeye fry scales were examined through a Carton microscope with a video monitor and aged using methods outlined in Mosher (1968). Two trained technicians independently aged each sample. The results of each independent scale ageing were compared. In instances of discrepancy between the two age determinations, a third independent examination was conducted. A proportion of each age class of sockeye fry is used to allocate the hydroacoustic sockeye fry estimates by age. Data were recorded onto a form and then entered into an MS EXCEL spreadsheet.

Data Analysis

We generated a fish density (targets $\cdot$ m^{-2}) for each of the transects using echo integration methods (MacLennand and Simmonds 1992). Data was analyzed using Biosonics Visual Analyzer © version 4.0.2 software. A mean target density for each sample section was calculated as the average of the two replicate transects. The mean target density for the whole lake was calculated as a weighted average of target density per section, with the area of each section as the weights. A target estimate for each of the sample sections was calculated as the product of the mean target density and the surface area of each of the sample sections. Summing the section estimates generated a total target estimate for the whole lake. The variance of this total target estimate was calculated based on 1 degree of freedom estimates for each pair of transects in each section. Because each section was sampled independently from other sections, the estimated sampling variance for the whole lake estimate was calculated as the sum of the target estimate variances for each section. Sampling error for the estimate of total targets for the whole lake was measured and reported using coefficient of variation (CV; Sokal and Rohlf 1987). A CV greater than 10% will necessitate adding additional sample sections to Hetta Lake the next year.

The apportionment of targets into species composition categories allowed us to get a rough estimate of sockeye fry abundance in those lakes where we had adequate trawl data. An obvious way to estimate the sockeye fry abundance in the entire lake is to simply pool all fish caught in all trawl samples (except the surface tow) into one sample, calculate the proportion of sockeye fry in the pooled sample, and then use this proportion to adjust the estimate of total sonar targets in the lake to an estimate of total sockeye fry. Although this approach should give a reasonable and very usable estimate of the number of sockeye juveniles present in the lake, unfortunately, this approach leaves us without a means to estimate the sampling error in the estimate.

We first assumed that sockeye fry are completely randomly distributed within the lake, and therefore within the multiple trawl samples. If so, we reasoned that the estimate of sampling error could be based on an approximation to the binomial distribution, which is well studied, and formulas for confidence intervals or standard errors can be found in any elementary statistical textbook. We began by developing rules for sample size requirements and using chi-squared tests for heterogeneity to test for similarity among trawl samples. We reasoned that if we had greater than 30 fish targets per trawl sample, if the assumptions of the chi-squared test we met (greater than 5 expected counts per cell and a fairly uniform distribution), that small observed chi-squared statistics would mean that the binomial approximation would be a usable assumption. However, we found that we had inadequate sample sizes to compare trawls at the same depth with these chi-squared tests. When we pooled the samples into one or more depth categories, in general we got small chi-squared statistics with small sample sizes and lager chi-squared statistics with larger sample sizes. In the end, we concluded that a simple, defendable estimate of the variance associated with the estimate of the proportion of sockeye fry is not possible because of the non-uniform distribution of sockeye fry in the lake, the clustering of sockeye fry within the samples and the small sample sizes. If we assume that the distribution is clumped, a negative binomial distribution to account for the clusters could be used if we had adequate trawl samples at each depth. It is a fairly complex problem to figure out what is an adequate sample. The biometrician has agreed to work on this using existing data.

Sockeye Escapement Assessment

A two-sample mark-recapture program was used to estimate the sockeye salmon escapement to the study area in Hetta Lake. The study area was defined as Hetta Creek from the mouth (Latitude N 55° 11.24 Longitude W 132° 32.08’) to a barrier falls located at (Latitude N 55° 11.475’, Longitude W 132° 32.356’) and approximately 500 m of beach delineated by the northwest end point (Latitude N 55° 11.182’, Longitude W 132° 32.211’) and the northeast endpoint (Latitude N 55° 11.233’, Longitude W 132° 31.803). The field crew conducted four mark-recapture sampling efforts, approximately every two weeks over the entire spawning period. At the beginning of each trip, the number of spawners around the lake and in tributary streams was estimated to provide an escapement index. The first component of the two-sample mark-recapture study was the marking of fish at the mouth of Hetta Creek. Marking was conducted using a beach seine 20 m long and 4 m deep to surround sockeye salmon, pulled by a skiff with outboard motor and crewmembers on foot. All sockeye salmon caught were first inspected for previous marks, then marked with an opercle punch or pattern of punches indicating the trip number, and released with a minimum of stress. The total sample size, the number of new fish marked, and the number of recaptured fish with each type of mark were recorded. Marking was stratified through time. The second component of the two-sample mark-recovery study was the recapture portion, conducted in the study area and in Hetta Creek. Live and dead fish were counted and examined for marks and given a second mark (opercle punch) to prevent duplicate sampling at a later time.

Escapement surveys of spawning sockeye salmon in Hetta Lake were used to describe the distribution of spawning sockeye salmon in the lake and its tributaries. Streams were walked and sockeye salmon counted by technicians wearing polarized sunglasses. Hetta Creek was walked from the mouth to the barrier falls. Other Creeks including Hatchery Creek (Latitude N 55° 09.981, Longitude W 132° 33.280) were also inspected for spawning fish. However, since no fish were seen in these streams the extent of the surveys was limited to the first 100m up stream from the mouth. Shoreline surveys from the boat were also conducted to count beach spawning congregations.

Data Analysis

We estimated the number of sockeye spawners in the study area using a Chapman's modification of the Petersen (Seber 1982) and Stratified Population Analysis System (SPAS) software (Arnason et al. 1996).

$$\hat{N} = \frac{(m+1)(c+1)}{(r+1)} - 1 \qquad (1)$$

Where: $\hat{N}$ = estimated abundance of sockeye salmon escapement:
m = number of marked sockeye salmon;
c = number of adults inspected for marks; and
r = number of adults with marks in samples.

The conditions for accurate use of this methodology are that all sockeye salmon within a strata:

1. have an equal probability of being marked; or

2. have an equal probability of being inspected for marks; or
3. marked fish mixed completely with unmarked fish in the population between events; and
4. it is a closed population; and
5. there is no tag-induced mortality; and
6. fish do not lose their marks and all marks are recognizable.

The standard error of that estimate will be calculated as

$$\text{SE} = \sqrt{v\left(\hat{N}\right)} \tag{2}$$

Where *v* (*N*) is

$$v\left(\hat{N}\right) = \frac{(m+1)(c+1)(m-r)(c-r)}{(r+1)^2(r+2)} \approx \frac{\hat{N}(m-r)(c-r)}{(r+1)(r+2)} \tag{3}$$

In the pooled Petersen mark-recapture equation used to estimate $\hat{N}$, *r* is a random variable, and it can be assumed to follow a Poisson, binomial, or hypergeometric distribution, depending on the circumstances of the sampling. Moreover, when *r* is large compared with the size of the second sample, *c*, its distribution can be assumed to be approximately normal (a practical check is to ensure *r* is at least 30 before using the normal approximation). Let $\hat{p}$ be an estimate of the proportion of marked fish in the population such that $\hat{p} = \frac{r}{c}$. We used approximate confidence interval bounds for $\hat{p}$ based on the assumption that *R* follows a hypergeometric distribution. We defined the confidence bounds for $\hat{p}$ as ($a_{0.025}$, $a_{0.975}$). Then the 95% confidence interval bounds for the Petersen population estimate, $\hat{N}$, were found by taking reciprocals of the confidence interval bounds for $\hat{p}$, and multiplying by *m*. That is, the confidence bounds for the Petersen estimate are given by ($m * 1/a_{0.975}$, $m * 1/a_{0.025}$).

Sample size criteria are given in Seber (1982, p. 63). If $\hat{p}$ = 0.1, and the size of the second sample *C* is at least the minimum given as follows:

$\hat{p}$ (or 1- $\hat{p}$)	0.5	0.4	0.3	0.2	0.1
minimum *C*	30	50	80	200	600

a 95% confidence interval for $\hat{p}$ is given by

$$\hat{p} \pm \left[1.96\sqrt{\left(1-\frac{c}{\hat{N}}\right) * \hat{p}(1-\hat{p})/(c-1)} + \frac{1}{2c} \right], \text{ (Seber 1982, eq. 3.4).} \qquad (4)$$

and the 95% CI bound for the estimated *N* is

$$95\%CI_{N*} = m * \frac{1}{95\%CI_{\hat{p}}} \qquad (5)$$

Escapement Age and Length Distribution

Scales, sex and lengths of the adult sockeye salmon were collected at Hetta Lake during the mark-recapture study to describe the biological structure of the population. The goal was to collect 600 samples through the spawning season. Three scales were taken from the preferred area of each fish (INPFC 1963), and prepared for analysis as described by Clutter and Whitesel (1956). Scale samples were aged at the ADF&G salmon aging laboratory in Douglas, Alaska. Age classes were designated following the European aging system where freshwater and saltwater years are separated by a period (e.g., 1.3 denotes 1 year freshwater and 3 years saltwater). Brood year tables were compiled by sex and brood year to describe the age structure of the returning adult sockeye salmon population. The length of each fish was measured from mid eye to tail fork to the nearest millimeter (mm).

The proportion of each age-sex group *k* and associated standard errors of the proportions were calculated by the standard binomial formula:

$$\hat{p}_k = \frac{n_k}{n} \qquad (6)$$

$$SE(\hat{p}_k) = \sqrt{\frac{\hat{p}_k(1-\hat{p}_k)}{n-1}} \qquad (7)$$

Where n_k is the number of samples in age-sex group k, n is the total number of samples aged, and N is the estimated escapement (Thompson 1992, p. 35-36).

The mean length and associated standard error for age-sex group k were calculated by standard normal methods:

$$\bar{y}_k = \frac{1}{n_k} \sum_{i=1}^{n_k} y_{ki} \tag{8}$$

$$SE(\bar{y}_k) = \sqrt{\frac{1}{{n_k}^2}} * \sqrt{\sum_{i=1}^{n_k} (y_{ki} - \bar{y}_i)^2} \tag{9}$$

(Thompson 1992, p. 42-43).

Subsistence Harvest Estimate

The study design for the Hetta Lake subsistence fishery harvest survey was originally based on a stratified two-stage direct expansion (Bernard et al. 1998; Cochran 1977). The nature of the subsistence fishery did not allow interviewers to follow the study design because of multiple exits between the harbor and the fishery. In 2002, the same procedure as the previous year was used whereby the HCA technicians were able to independently interview all participants and all that was required was summation of catches.

The total harvest (by species) ($\hat{H}$) was estimated as:

$$\hat{H} = \sum_{i=1}^{d} \sum_{i=1}^{m_i} h_{ij} \tag{5}$$

Where h_{ij} = harvest on boat group j, sampling day (period) i; m_i = number of boat groups interviewed on day i; M_{i} = number of boat groups completing trips on day i (in case where all boats are interviewed, $M_{\text{i}} = m_{i)}$; d = number of days sampled; and D = number of all days the fishery is open (in case where all days are sampled, $D = d$).

The HCA technicians sampled every day that the fishery was open, and interviewed every party that fished. If the technicians were unable to interview participants in the fishery or at the boat harbor, they would contact participants at their homes. The technicians were certain that they had interviewed all participants in the fishery.

Limnology

Limnology sampling was conducted at two stations on Hetta Lake every six weeks throughout the summer to measure euphotic zone depth, and to collect zooplankton samples. Light, temperature and dissolved oxygen profiles were collected at the primary sample site, Station A. We used sampling methods described in Koenings et al. 1987.

RESULTS

Sockeye Fry Assessment

A hydroacoustic survey and mid-water trawls were conducted on July 18, 2002. A total of 127 sockeye salmon fry and 31 sticklebacks were caught in the mid-water trawl samples collected in the area showing a high density of targets in the hydroacoustic survey. The trawl effort consisted 5 tows: a single 15-minute tow at the surface (1 m), two 15-minute tows at 7.5 m, and two 15-minute tows at 10 m (Table 1). All 127 sockeye salmon fry were age-0 except a single age-1 fry that had a snout-fork length of 45 mm. The length frequency for sockeye salmon fry similarly shows one age class with a normal distribution (Figure 3). The mean snout-fork length of the sockeye salmon fry was 35.3 mm (SE = 0.3 mm) and a mean weight of 0.33 g (SE = 0.01 g). The mean snout-fork length of sticklebacks was 38.2 mm (SE = 0.7 mm) with a mean weight of 0.53 g (SE = 0.04 g). All targets that fell within target strength range of –40 dB to –68 dB during hydroacoustics were assumed to be 80% sockeye fry and 20% sticklebacks. We estimated a total lake population to be roughly 1.02 million sockeye fry with a density of 0.44 fry $\cdot$ m^{-2} and 250,000 stickleback (Table 2). The 2002 sockeye fry estimate was one-third the population estimate in 2001 (3.07 million sockeye fry).

Sockeye Escapement Assessment

In 2002, five trips were performed in Hetta Lake on August 14 and 30, September 11 and 25, and October 10. No marks were applied during the first trip on August 14. During the next three trips, we marked a total of 189 sockeye salmon; 128 circle, 48 triangle, and 13 square punches (Table 3). Of the 145 fish caught in the recovery phase of the project, 83 (57%) were marked and 62 were unmarked (Table 4). The estimated sockeye salmon population in the study area was 329 (SE = 17, CV = 5.3%). Because the proportion of marked fish in the population ($\hat{p}$) was greater than 0.1 (0.57), R was greater than 30 (83), and C was greater than 30 (145), we used equation 3.4 in Seber (1982) to estimate the 95% CI around the point estimate; 269-427 sockeye salmon.

Three escapement surveys were completed between August 30 and October 10 to create an index of the number of spawners (Table 5). Hetta Creek was the only tributary that had spawning sockeye salmon. However, on the last two trips, over half the sockeye salmon counted were outside the study area. Most of these fish were concentrated along the beaches near Hatchery Creek. The peak sockeye salmon count of 404 fish for the entire lake and stream was on September 25 (Table 5).

Escapement Age and Length Distribution

A total of 236 adult sockeye salmon scale samples were aged in 2002. The dominant age class of adult sockeye salmon, weighted by the number sampled per week, was age-1.2 (69.9%) followed by age-1.3 (22.5%; Table 6, Appendix 1). The mean fork length of age-1.2 fish was 499 mm (SE = 2.4 mm; n = 163) and 569 mm (SE = 2.7 mm; n = 53) for age-1.3 fish (Table 7; Appendix 1).

Subsistence Harvest Estimate

The Hetta Lake sockeye salmon subsistence fishery harvest estimated by creel survey was 947 fish in 2002. Because all participants in the fishery were interviewed, there was no variance. Twenty-eight creel survey interviews were conducted during the subsistence fishery season. The reported harvest from 11 returned subsistence permits, was 199 sockeye salmon. The majority of the sockeye salmon were harvested at the end of July and beginning of August (Figure 4). The reporting rate on the mail-in surveys was about 20% of the sockeye harvest estimated during the creel interviews. During the on-grounds interviews, the Hetta crew also recorded 1,242 sockeye adults from 37 interviews were harvested in Eek Inlet and 1,232 sockeye salmon from 10 interviews in the Kasook Lake area.

At the time of the 2001 annual report (McEwen et al., 2002), the number of fish reported on permit returns was not available. The final number of sockeye salmon reported on returned permits in 2001 was 1,089, only 25% of the harvest estimated during the creel survey on the fishery grounds (4,400 sockeye salmon; Figure 5).

Limnology

Vertical Light Penetration, Temperature, and Dissolved Oxygen

In 2002, limnology sampling was conducted at Station A on Hetta Lake on May 9, June 12, July 18, August 30, and October 9, to measure temperature, dissolved oxygen, euphotic zone depth. Zooplankton samples were also collected at both stations on each sampling date. The euphotic zone depth (EZD) ranged from 6.4 to 12.5 m with a season mean of 10.2 m. Typical of other Southeast Alaskan lakes; this lake was clearest in the late spring, becoming more stained throughout the season (Table 8).

Water temperature and dissolved oxygen vertical profiles for Station A in 2002 show largely isothermal conditions in May, stratification through summer months, and weak stratification remaining on October 9 (Figure 6). Peak epilimnetic temperature was 15.5^{o} C on July 18, 2002. Hypolimnetic temperatures were in the 4.0 ^{o} C range. Dissolved oxygen (DO) levels for 2002 ranged between 8.6 and 13.0 mg $\cdot$ L^{-1} (85- 100% saturation) with a season mean of 10.7 mg $\cdot$ L^{-1} (Figure 6).

Secondary Production

Zooplankton samples were collected at stations A and B on Hetta Lake on May 9, June 12, July 18, August 30, and October 9. In 2002, similar to 2001, the macro-zooplankton densities (no./m^2) in Hetta Lake were dominated by a *Bosmina* spp.; 56% of the mean seasonal density was bosminids in 2002 and 40% in 2001 (Table 9; McEwen et al., 2002). The mean weighted biomass (mg/m^2) of bosminids increased 12% between 2001 (49%) and 2002 (62%; Table 10). This suggests that the increase in biomass was due mostly to numbers of bosminids, not size (Table 11). Although the proportion of *Cyclops* spp. in 2002 (15%) remained similar to 2001 (16%), the biomass percent composition decreased 50% between 2001 (48%) and 2002 (25%; Table 10). This suggests that the size of *Cyclops* declined in 2002. The decline in the mean length of *Cyclops* from .71 mm to .63 mm (11% decline) accounts for some but not all of this decrease in biomass (Table 11). This is because the conversion of length to weights to calculate biomass is not linear (see Koenings et al. 1987 for details). In 2002, the most preferred food of sockeye fry, *Daphnia* spp., increased substantially from 2001. The mean seasonal density of *Daphnia longiremis* was 1,954 no./m^2 in 2002 compared to 97 no./m^2 in 2001. *Daphnia l.* biomass also increased between 2001 (0.19 mg/m^2) and 2002 (4.3 mg/m^2).

DISCUSSION

The 2002, mark-recapture study encountered similar problems as the prior year (McEwen et al., 2002). For the second year, Hetta Lake sockeye returns to the lake were very low. Consequently, we were unable to capture, mark and recapture enough sockeye spawners to estimate the escapement this year. The dispersal of fish from the staging area at the mouth of Hetta Creek along the beach further exacerbated the problem because we are unable to use a beach seine in most of this area. However, the study area (Hetta Creek and the adjacent beach) had the highest concentration of spawning fish and remains the best location for a mark-recapture study. Similar to Kook and Kutlaku lakes, a beach spawning population enters the lake later in the season. In the last two trips of the 2002 season, over half the fish observed were outside the study area, spawning along the beach. In 2003, we will explore the possibility of creating a second study area near Hatchery Creek, the highest concentration of sockeye spawners in the beach areas where a seine net can be used. If we continue to be unable to get a good estimate of the number of sockeye spawners returning to Hetta, we think Hetta Creek would be a good candidate of a weir.

After two years of stock assessment efforts, the status of the Hetta Lake sockeye stock remains uncertain. The 2002 escapement also appears to be even lower than the number of sockeye spawners returning in 2001. Robert Sanderson, a long-time Hydaburg resident, stated that it was the worst run he can remember. The 4-fold decline in subsistence harvest between 2001 and 2002 also supports our conclusion that very few sockeye spawners returned in 2002. According to the Hydaburg residents, the last large return was 2000, the year before the research at Hetta Lake began. Hetta Lake had the highest density of sockeye fry in Southeast Alaska in 2001, supporting the idea that the 2000 adult return was high. Results to-date suggests that the stock may be depressed or at best highly variable. Sockeye salmon populations are known to have highly variable escapement patterns. Results from only two years of monitoring do not provide conclusive evidence that the stock is either chronically depressed or just in a low cycle for a few years. Furthermore, depressed stocks could be due to chronic low number of returns or a high escapement year could depress the food base for several years (Koenings and Kyle 1997; Carpenter and Kitchell 1993). In other words, low production of sockeye salmon could be limited by the escapement or by food. Management actions would be very different depending on which hypothesis was considered true. These unresolved issues confirm the need to conduct multiple years of monitoring to determine the health of this important sockeye salmon stock.

A few years of data is not sufficient to come to any conclusions for several reasons. First, it takes two years to get a paired data set of adult returning and the number of fry produced the next fall. For example, we have two years of fry and adult data for Hetta and only have one data point; the 2001 adult estimate and 2002 fry estimate. Secondly, density independent factors such as climatic variation especially from the egg to fry stage can play a significant role in salmon fry production (Koenings et al., 1986). In addition, it takes many years of data to determine which density dependent factors are limiting production i.e., is it spawning area or zooplankton (food) production?

As mentioned in the methods, the variance around the sockeye fry estimate was unattainable due to the small trawl sample sizes and the clumped distribution of targets. We plan on spending enough time on this lake in 2004 to get an adequate sample by depth and area to perform a negative binominal distribution analysis. We will continue to do a hydroacoustic survey at Hetta because we want to know the egg to fry survival to evaluate whether this system is limited by food or escapement. Long-term objectives might be to fertilize this lake for 5 years, increase production coupled with management changes to ensure enough fish return to the area for the subsistence fishery and the escapement.

Nevertheless, a few patterns have emerged in the last two years that may help us start to see some of the relationships between trophic levels. For example, if we integrate information on what we know about the physical characteristics of the lake, climate variation between years, zooplankton production by species, sockeye fry production and adult returns, and local knowledge, relationships between these various trophic levels start to emerge. With the sharp decline in sockeye adult returns in 2001 and 2002, compared to 2000 observations by local residents, we would expect to see a high number of sockeye fry in the lake in 2001 followed by a substantial drop in fry numbers the next year. Indeed, we saw a 67% drop in fry estimates between 2001 and 2002. Because sockeye fry favor cladocerans (daphnia and bosminids) over other zooplankton species, we would also expect to see, and did see, an increase in cladocerans in 2002 compared to 2001. There was a 20-fold increase in Daphnia l. biomass estimates between 2001 and 2002. Similarly, *Bosmina* spp. biomass increased 12% between 2001 and 2002. The mean seasonal EZD (depth of 1% light level compared to surface light levels) was not that much different between 2002 (10 m) and 2001 (8 m). Unfortunately, other physical lake characteristics such as temperature, was not recorded in 2001, so the comparison cannot be made between years.

The ADF&G subsistence permit system began in 1985 and requires subsistence users to report their catches by species and area each year. Other estimates of the number of fish taken in the subsistence fisheries suggest that the harvest may be higher than what is reported on the permits (Tongass Resource Use Cooperative Study (TRUCS) 1988). Two years of collecting data on the fishery grounds confirms this discrepancy; only 20-25% of the subsistence harvest is reported on the ADF&G permits.

We now have 20 years of data on the age, sex and size of the adult sockeye salmon returning to spawn in Hetta Lake collected between 1982 and 2002 (Appendix 1 and 2). The 1.3 age class dominated the age structure in 15 of the 20 years and Age 1.2 fish dominated in five years including the 2002 population of spawners. Typical of sockeye salmon runs in Southeast, a strong Age 1.2 year usually is followed by a large proportion of Age 1.3 and this appears to be true at Hetta Lake (Appendix 2). The dominance of Age 1.2 fish in 2002 suggests that the Age 1.3 fish will dominate the age structure in 2003 (brood year 1998). Because the majority of sockeye adult returns are Age 1.3, this would predict a large return in 2003. However, because we do not have escapement and fishery harvest data (specific to Hetta Lake), the magnitude of the run is unknown.

This year's results provide information important to the Hetta Lake project but they represent only the preliminary steps in the construction of a complete sockeye stock assessment to be meaningful to managing these stocks for maximum production. A complete stock assessment requires, at a minimum, monitoring the sockeye adult and fry populations through a five-year life cycle followed by many years of re-evaluation of escapement goals. Additionally, we will continue to develop cooperative partnerships, jobs, and training opportunities for residents of Hydaburg.

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Table 1. Summary of tow netting results by tow, depth (m), time (min), species (sample size), mean length (mm) with standard deviation and mean weight (g) with standard deviation in 2002.

Tow	Depth	Time	Species	Sample size	Length	Weight
1	1	15	Sockeye age 0	1	33.0	0.4
			Stickleback	5	30.4 (4.7)	0.36 (.02)
2	7	15	Sockeye age 0	24	34.3 (2.1)	0.3 (0.1)
			Stickleback	20	39 (4.6)	0.6 (0.2)
3	7	15	no fish	0		
4	10	15	Sockeye age 0	13	34.6 (3.5)	0.3 (0.1)
			Stickleback	2	39 (7.1)	0.6 (0.2)
5	10	15	Sockeye age 0	88	35.6 (3.2)	0.3 (0.1)
			Sockeye age 1	1	45.0	0.7
			Stickleback	4	43.5 (5.7)	0.6 (0.2)

Table 2. Summary of hydroacoustic population and mid-water trawl abundance estimates of rearing sockeye salmon fry in Hetta Lake, 2002.

Species	Age	Sample size	Percent Species	Population	Mean length (mm)	Mean weight (g)
Sockeye	0	127	80%	1,020,000	35.3	0.3
Stickleback		31	20%	250,000	38.2	0.5

Table 3. Summary of sockeye salmon marking at Hetta Lake study area by date and mark type, 2002.

Date	Mark	Marked
Aug 30	Left Circle	128
Sept 11	Left Triangle	48
Sept 25	Left Square	13
Total		189

Table 4. Mark recovery data in Hetta Lake study area by date and mark type, 2002.

Date	Left circle	Left triangle.	Left square	Unmarked
Sept 12	27	4		31
Sept 26	24	20	1	26
Oct 10	4	2	1	5
Total	55	26	2	62

Table 5. Number of sockeye adults counted in 2002 surveys by date.

Date	Study Area	Outside Study Area	Lake Total
August 14	0	0	0
August 30	128	0	128
September 11	106	0	106
September 25	196	208	404
October 10	111	156	267

Table 6. Age composition of sockeye salmon by brood year, age, and percent sample size, 2002.

Brood year	1999	1998	1997	1997	1996	
Age	1.1	1.2	1.3	2.2	2.3	Total
Percent	3.8	69.9	22.5	3.4	0.4	100
Std. Error	1.2	3	2.7	1.2	0.4	
Sample Size	9	165	53	8	1	236

Table 7. Mean fork length (mm) of sockeye salmon in 2002 Hetta lake escapement by sex, brood year, and age class.

Brood year	1999	1998	1997	1997	1996	Total
Age	1.1	1.2	1.3	2.2	2.3	
Male						
Average Length	356	505	578	511		511
SE	8.7	2.9	2.8	17		4.6
Sample Size	8	103	26	4		141
Female						
Average Length	329	488	561	484	559	508
SE		4.2	3.9	18.4		5
Sample Size	1	60	27	4	1	93
All						
Average Length	353	499	569	498	559	510
SE	8.3	2.4	2.7	12.6		3.4
Sample Size	9	163	53	8	1	234

Data from ADF&G scale age lab.

Table 8. Euphotic zone depth in meters in Hetta Lake.

2002	EZD
May 9	12.4
Jun 12	12.5
Jul 25	10.9
Sept 6	8.7
Oct 17	6.4
MEAN	10.2

Table 9. Hetta Lake zooplankton species density (No./m^2) by station, date, and season mean, 2002.

Station A	May 9	Jun 12	Jul 18	Aug 30	Oct 9	Mean	Percent
Cyclops	15,436	9,883	849	10,324	7,539	8,806	19%
Bosmina	9,883	9,679	18,102	49,244	32,247	23,831	53%
Ovig. Bosmina	815	153	1,155	883	815	764	2%
Daphnia l.	102	255	442	204	458	292	1%
Copepod nauplii	16,913	2,089	577	11,071	26,490	11,428	25%
Station B							
Cyclops		6,113	7,472	6,656	11,819	8,015	13%
Bosmina		6,623	29,445	57,259	52,097	36,356	59%
Ovig. Bosmina		102	815	1,291	4,347	1,639	3%
Daphnia l.		170	34	5,841	8,422	3,617	6%
Copepod nauplii		2,649	1,698	18,475	25,200	12,006	19%

Table 10. Hetta Lake zooplankton mean weighted biomass (mg/m^2) by station, species, and season mean, 2002.

Species	Station A	Percent	Station B	Percent	Mean	Percent
Cyclops	12.2	35%	11.4	19%	11.8	25%
Bosmina	21.1	60%	36.4	62%	28.8	62%
Ovig. Bosmina	1.1	3%	2.7	5%	1.9	4%
Daphnia l.	0.6	2%	8.1	14%	4.3	9%
Total	34.9		58.6		46.7	

Table 11. Hetta Lake zooplankton mean species length (mm) by date and season mean, 2002.

Species	9-May	12-Jun	18-Jul	30-Aug	9-Oct	Mean
Cyclops	0.54	0.57	0.58	0.75	0.71	0.63
Bosmina	0.36	0.32	0.33	0.32	0.32	0.33
Ovig. Bosmina	0.45	0.41	0.35	0.42	0.43	0.41
Daphnia l.	0.61	0.63	0.70	0.68	0.74	0.67

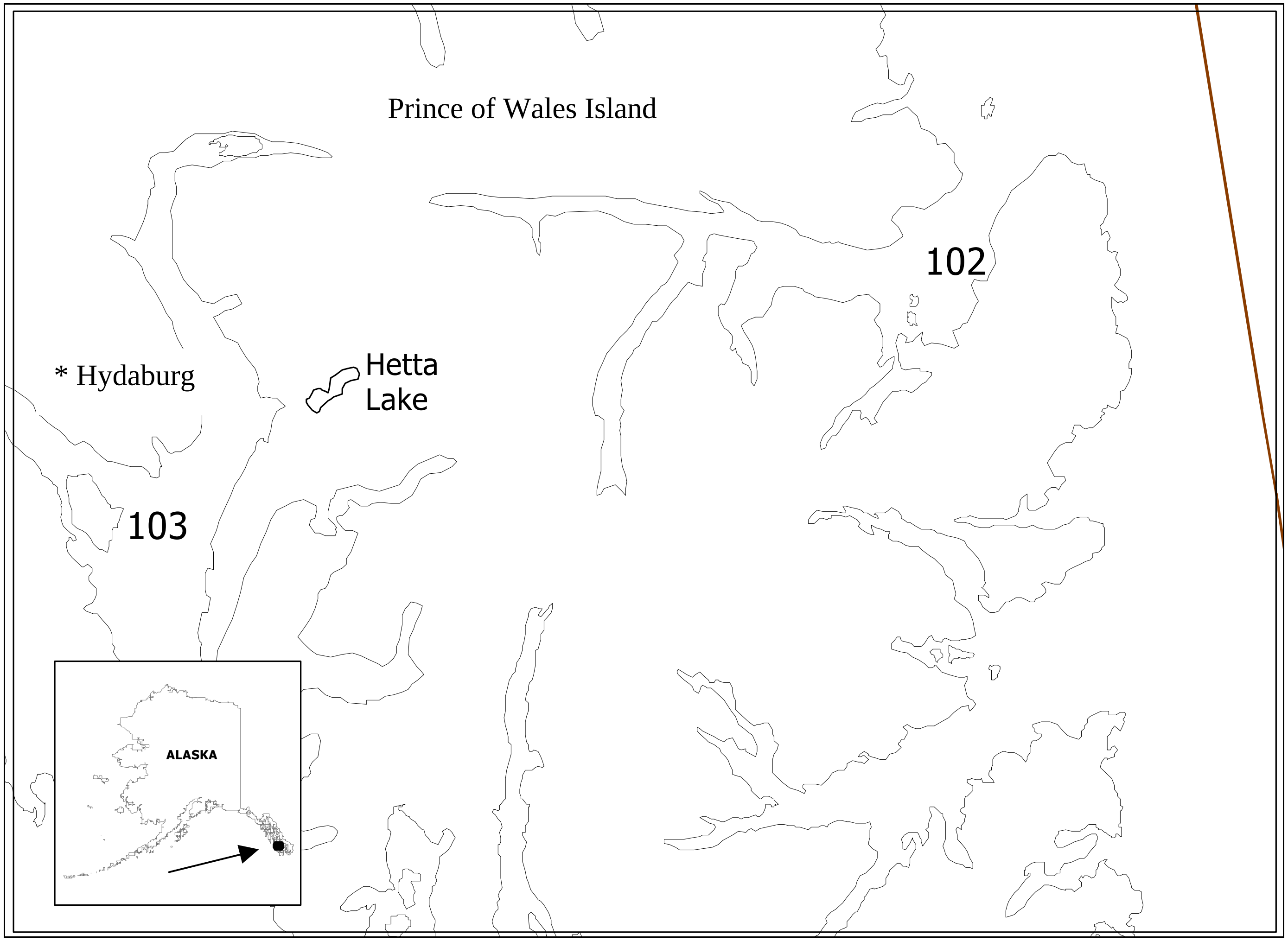

Figure 1. The geographic location of Hetta Lake, within the State of Alaska, and relative to commercial fishing districts on southwest Prince of Wales Island.

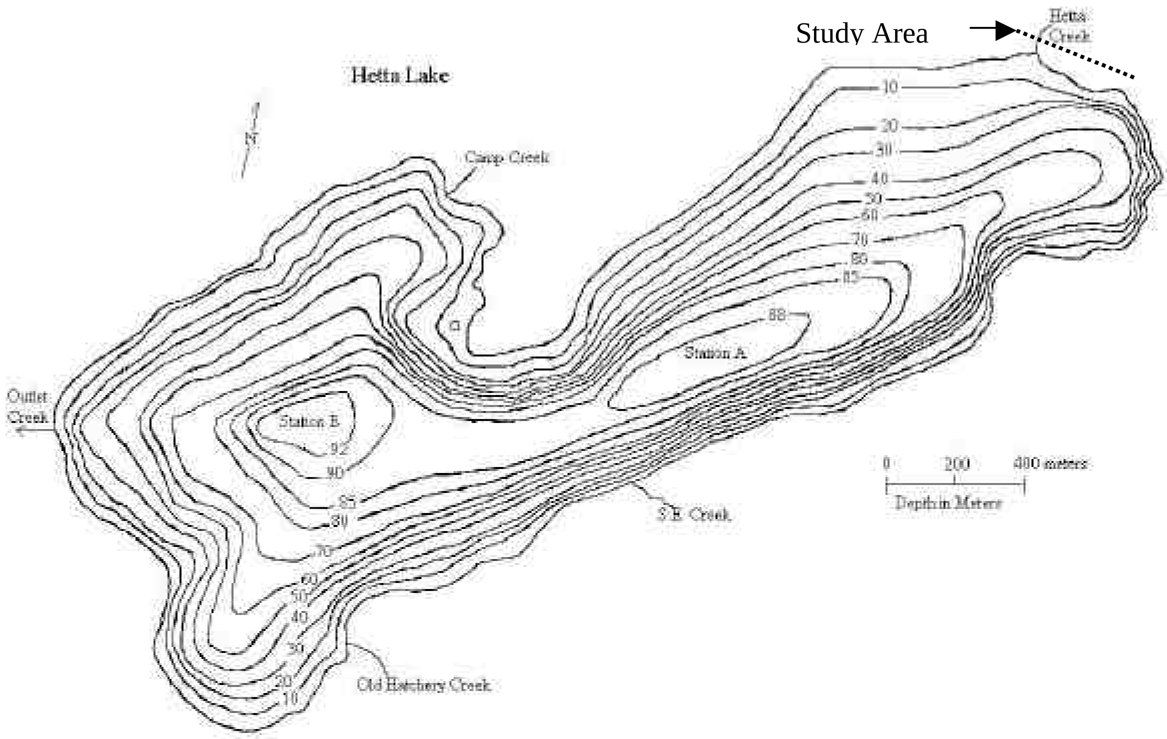

Figure 2. Bathymetric map of Hetta Lake, Southeast Alaska with limnological sampling stations and inlet stream references.

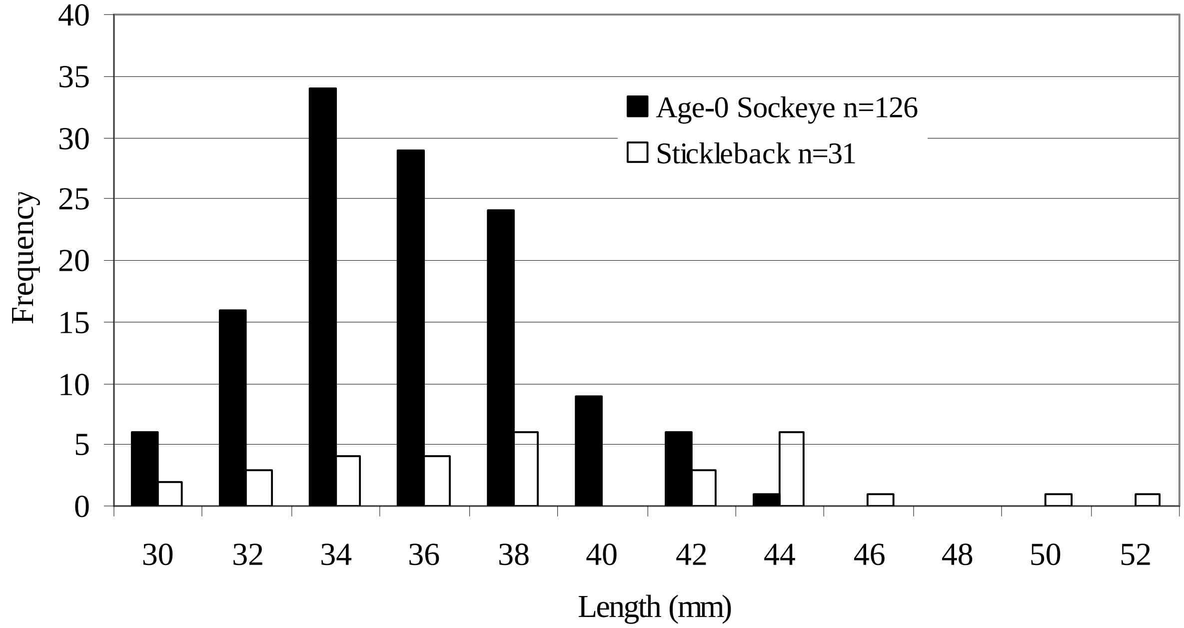

Figure 3. Length frequency of age-0 sockeye salmon fry and stickleback from hydroacoustic trawl catch.

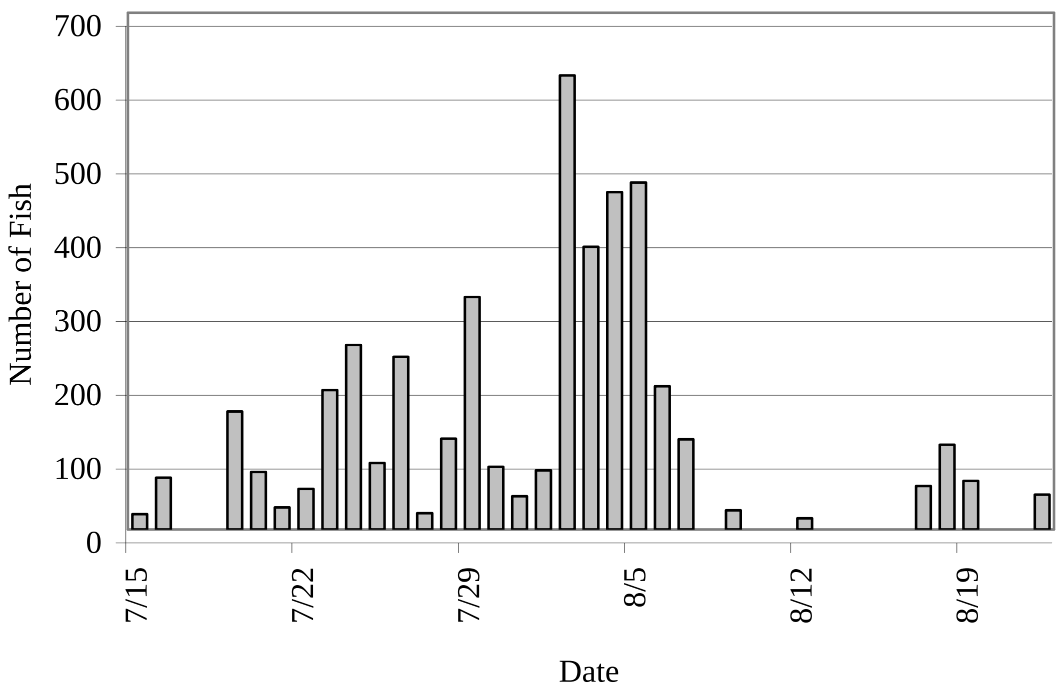

Figure 4. Estimated Hetta Lake subsistence harvest of sockeye salmon by sampled dates in 2002.

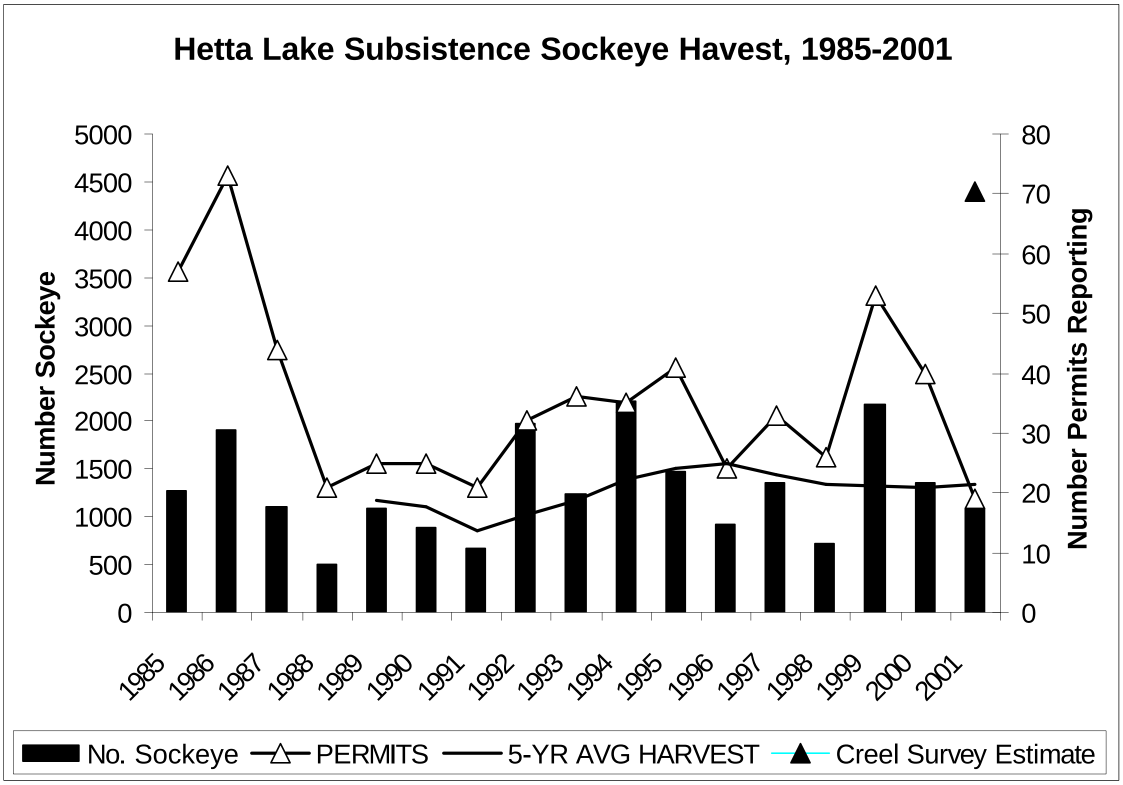

Figure 5. The annual reported subsistence harvest in the marine terminal area at Hetta Lake, number of permits, and the five-year reported catch average. In 2001, the creel survey estimate on the fishing grounds is represented by a solid triangle (?).

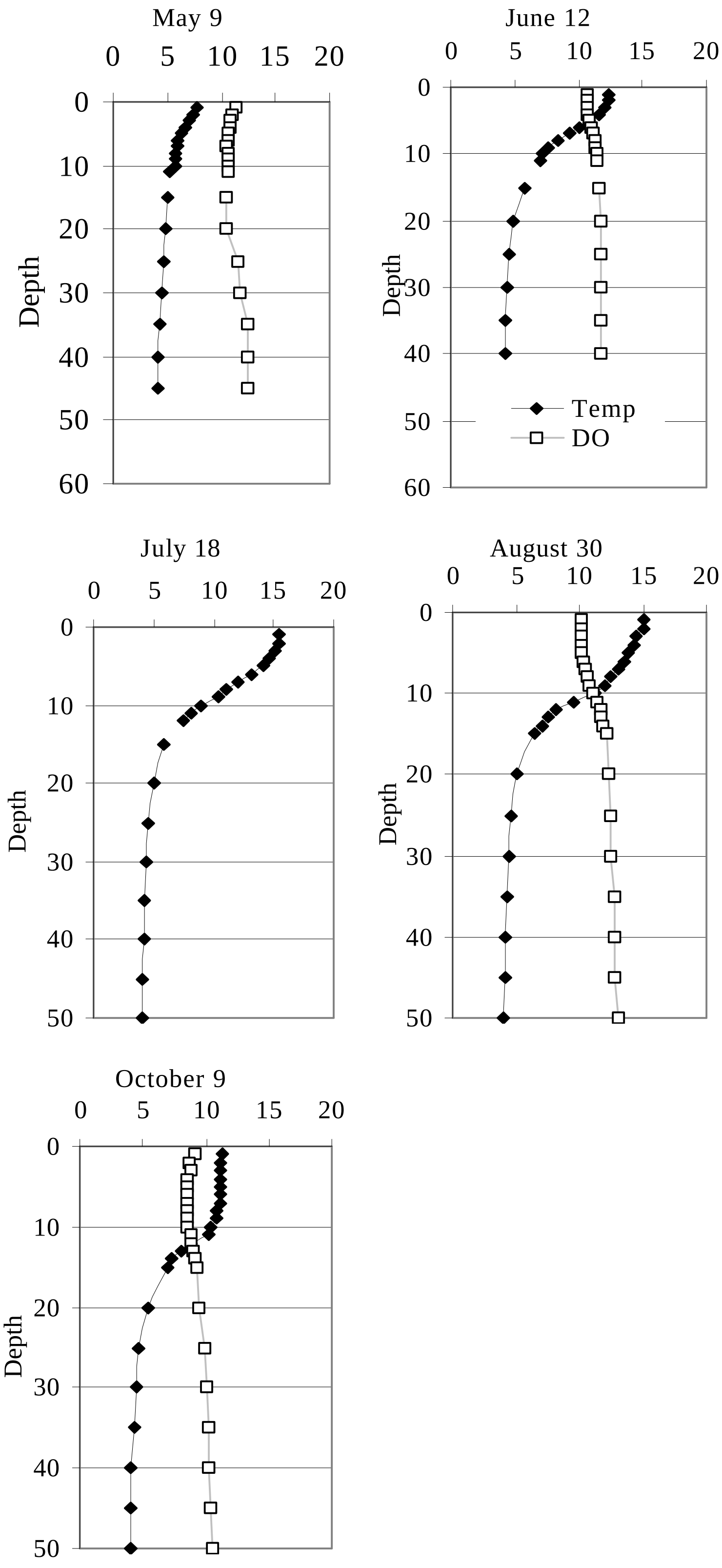

Figure 6. Temperature (°C) and dissolved oxygen (mg · L^{-1}) vertical (in meters) profiles by date in Hetta Lake, 2002.

APPENDIX

Appendix A.1a. Numbers of fish sampled in Hetta Lake sockeye salmon escapement by age and sample year, 1982-2002.

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
0.3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1	0	13	42	53	3	3	21	0	14	65	22	0	47	174	0	2	111	8	0	5	9
1.2	52	30	100	119	207	7	182	0	187	144	227	127	42	263	174	19	32	287	80	85	165
1.3	686	71	56	247	187	346	160	0	260	333	281	358	468	65	352	498	79	91	289	410	53
1.4	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
2.1	0	0	0	0	0	0	0	0	1	1	0	0	1	29	0	0	4	0	0	0	0
2.2	0	0	1	2	9	0	6	0	6	3	8	4	2	2	6	3	2	15	4	1	8
2.3	2	0	0	15	8	6	1	0	5	6	5	34	8	5	0	6	3	2	13	7	1
Total	745	114	199	436	414	362	371	0	473	552	543	523	568	539	532	528	231	403	386	508	236

Appendix A.1b. Percent of fish sampled in Hetta Lake sockeye salmon escapement by age and sample year, 1982-2002.

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	AVG	SE
0.3	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1	0	11.4	21.1	12.2	0.7	0.8	5.7	0	3	11.8	4.1	0	8.3	32.3	0	0.4	48.1	2	0	1	3.8	6.8	0.3
1.2	7	26.3	50.3	27.3	50	1.9	49.1	0	39.5	26.1	41.8	24.3	7.4	48.8	32.7	3.6	13.9	71.2	20.7	16.7	69.9	29.2	0.5
1.3	92.1	62.3	28.1	56.7	45.2	95.6	43.1	0	55	60.3	51.7	68.5	82.4	12.1	66.2	94.3	34.2	22.6	74.9	80.7	22.5	61.1	0.5
1.4	0.1	0	0	0	0	0	0.3	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0
2.1	0	0	0	0	0	0	0	0	0.2	0.2	0	0	0.2	5.4	0	0	1.7	0	0	0	0	0.4	0.1
2.2	0	0	0.5	0.5	2.2	0	1.6	0	1.3	0.5	1.5	0.8	0.4	0.4	1.1	0.6	0.9	3.7	1	0.2	3.4	0.9	0.1
2.3	0.3	0	0	3.4	1.9	1.7	0.3	0	1.1	1.1	0.9	6.5	1.4	0.9	0	1.1	1.3	0.5	3.4	1.4	0.4	1.5	0.1

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